MASTER'S THESIS

Conformance checking between a simplified generally accepted process model by use of a Petri net and a dataset of event logs

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Award date:
2020

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Date:	June 21, 2020
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Version number:	1.0 (AF)
Status:	Final

Abstract

This research focuses on conformance checking between a simplified generally accepted process flow and an existing dataset. The dataset is retrieved from the BPI Challenge 2019, which includes a purchase order handling process. The dataset of the purchase process is explored by use of business process mining, specifically using the research technology ProM. The business case used within this research is specified towards the purchase process. The simplified generally accepted process flow is set up within this research by use of a Petri net, in which the process flow is extended with the actual payment of the purchases. The research proposes and then evaluates a conformance checking technique. In doing so, the theoretical and practical benefits and disadvantages of conformance checking between a generally accepted process flow, as set up within a Petri net model and containing a fairly limited number of process steps, and event log are elaborated upon during the research. The benefits and disadvantages are herein related to the outcome of the proposed method and the corresponding gain in insights. As such, this research contributes to the current literature with respect to business rule mining.

Key terms

Business rule mining, conformance checking, generally accepted process flow, ProM, purchase process, BPI Challenge 2019

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1. Introduction

1.1. Background

This research is focused on business rule mining, in which a technique is investigated towards conformance checking between a simplified generally accepted process flow and a dataset with event logs. The simplified and generally accepted process flow is referred to as a number of certain process steps that are (1) generally accepted within a process and (2) are relatively simplified as it does only contain certain key process steps of a process. Generally, enterprises have for instance a purchase process, in which the process flows can deviate from entity to entity. However, certain key process steps are generally implemented and accepted by a great number of enterprises, such as the authorization of payments. This research focusses on these generally accepted process steps, which are deemed of relevance of a great number of enterprises.

The simplified generally accepted process flow is set up by use of a Petri net model. The business case used in order to perform the research is the purchasing process, starting from the purchase order towards the clearance of the invoice. The problem domain mainly focusses on conformance checking of a simplified generally accepted process model, containing a limited number of event types, with a complete event log. The purchasing process is used as the business case in order to research the possibilities and the proposed method. The event logs are derived by use of dataset from a large multinational company operating from The Netherlands in the area of coatings and paints (van Dongen, 2019).

1.2. Scientific exploration

In the current century, it is apparent that (big) data is becoming more and more important. Enterprises are increasingly implementing data-driven decision making as they recognize the importance and possibilities of their data.

In order to support the daily operations of the enterprises, business organizations use information systems, like enterprise systems for enterprise resource planning, supply chain management and customer relationship management. Such information systems, no matter whether they are process-oriented and explicitly produce so-called process log data, or not, generate data. This data can serve to obtain a view of the underlying business processes (C. Houy, Rehse, JR., Schneid, M., Fettke, P., 2019). The data generated by the information system can also serve for data-driven decision making. Key towards data-driven decision making is that the decisions made are substantiated by historic data, instead of decisions made intuitive or based on an observation (Isaacs, 2003).

The methodology of data-driven decisions can also be applied to gain insights into how business processes are handled within organizations. A set of real process executions, also referred to as event logs, can be seen as a historic dataset, and as such can be used for process discovery and conformance checking (Rozinat, 2006). An adequate analysis of these process executions can give insights in the actual execution of processes, which could be different than the design of the processes, therefore can be used to identify any abnormalities.

The Process Mining Framework (ProM) is a well-known Open Source framework for process mining. The ProM process mining technology can be used towards exploring and researching your own dataset ("ProM Framework," 2017). ProM is a software environment specified for process mining, which includes a variety of add-ins for among others process discovery and conformance checking, both add-ins that are of relevance within this research.

The most relevant data to be used within ProM are event logs. As indicated, an event log is a collection of traces which represent process instances that have been executed. ProM provides several different process discovery algorithms. Several conformance checking related algorithms are present that allow the user to assess the conformance of an event log to a process model and vice versa (Van der Aalst, 2017). As such, as ProM is specifically designed for process exploration and conformance checking. In this research ProM is argued the most appropriate framework and methodology towards exploring the dataset.

1.3. Problem statement

This research is aimed to explore the possibilities in relation to conformance checking between a simplified generally accepted process flow and dataset which includes event logs. In this regard, it is researched if a simplified generally accepted process model can be compared with a complete dataset containing event logs. A dataset with event logs usually would have a great number of event types and different process flows. A simplified model would only contain one or a limited number of event types and process flows. The research uses a business related to the purchasing process domain. A research method is created in order to analyze the differences between the simplified generally accepted process flow and a dataset. In order to do so, a part of this research, the generally accepted process flow is set up by use of Petri net and the data, which includes the event logs, is discovered by use of the operators within Prom.

The following problem statement is defined: how, when and to what extent can a method be developed that can compare a simplified generally accepted process flow, which is included within a Petri net model and contains only a limited number of relevant process steps, with a dataset which includes a complete set of event logs?

It is noted that the problem statement does not specifically address the research domain, which is due to the reasoning that the method could generally be used, not only being pinpointed towards the purchasing process. Nevertheless, in order to perform the research, the purchasing process is chosen to be the research domain.

1.4. Objective and research questions

The objective of this research is to explore the possibilities in relation to setting up a comparison between a simplified generally accepted process flow and an existing dataset. Such a comparison can be achieved when the general process flow and the existing dataset are comparable, for instance when both are documented in a process flow diagram by use of Petri net. As such, in order to compose a method, the objective is to explore if and how a comparison can be set up, analyzing the differences between a general process flow and an existing dataset. Consequently, taking into account the problem statement and the aforementioned objective, the following experimental research questions are deemed relevant:

- How and where can a Petri net model contribute to performing a conformance analysis?

- Which method of process mining can be used towards effectively exploring the purchasing process within an existing dataset?
- By use of what method can a simplified generally accepted process flow be constructed with respect to the purchasing process?
- Can a simplified generally accepted process flow and a dataset with event logs be summarized in such a manner that these can be compared?

1.5. Overall treatment

At first, this research contains a theoretical disposition of the relevant literature in relation to business rule mining, the conformance analysis and other relevant elements. Thereafter, the research methodology is explained and elaborated upon. This chapter contains the design and the proposed execution of the research. Subsequently, the results of the research are described and to follow through on these conclusions the last chapter contains further discussion on the overall conclusions and need for additional research.

2. Theoretical framework

This research focuses on exploring the possibilities with respect to conformance analysis between a generally accepted process flow and an existing dataset in relation to a purchase process, which is the application domain. Therefore, multiple elements should be taken into account within the research, including the theoretical framework. As a start of the process, in order to perform and facilitate the research technique between the generally accepted process flow and the existing dataset, the business rules within the existing dataset have to be derived. These business rules, based on the existing dataset, are used to set up an overview that contains the actual process flow of the purchase process. Therefore, the theoretical framework will focus first on mining the business rules from an existing dataset and composing a process flow, being the “as is” situation. The “as is” situation usually describes the current situation of the business rules within an entity, and as such can also describe the business processes. Thus, the “as is” is referred to the business rules and processes that can be derived from the existing dataset and therefore gives a representation of the current business rules and processes.

As a result of the aforementioned, the research contains two process flows, being the “as is” situation derived from the existing dataset and the “to be” situation. The “to be” situation usually describes the desired situation of the business rules and processes within an entity. In other words, the “to be” is defined as the business ruleset that management has designed for a certain process, which is deemed as idealistic for that entity. In this research, the “to be” situation and the predefined ruleset are deemed equal and as such are defined as the generally accepted process flow. Thus, the generally accepted process flow is the ruleset that can be referred to as the idealistic business ruleset. However, actual implementation of the rules, being the “as is” situation, could strongly differ. As such, a theoretical disposition towards a conformance analysis, specifically between the “as is” and “to be” situation, is included the theoretical framework.

2.1. Research approach

The research approach is basically divided towards researching the theoretical framework in relation to business rule mining by use of an existing dataset and towards performing a comparison analysis between the “as is” and the “to be” situation. The goal is to understand the theoretical aspects of both of the aforementioned elements and to gain a theoretical answer on the research questions that are defined in chapter 1.4.

To gain sufficient understanding this research used multiple academic literature databases, which mainly include literature towards information and business systems. The literature databased used include Google Scholar, Open University Library, Academic Search Elite (EBSCO), Electronic Journals Service (EBSCO) and Library Information & Technology Abstracts (EBSCO). Keywords used within the search for relevant litetaure are “process mining”, “business rules”, “business rule mining” in combination with search terms such as “variance analysis”, “conformance checking” and “process variance analysis”. Furthermore, the search for academic literature included specific elements such as business rule mining, purchase process, generally accepted process flow, Petri net, variance analysis and process models. As a result of these elements, sufficient academic literature is retrieved towards composing the theoretical framework. Furthermore, the BPI Challenge 2019 data is analyzed in order to perform this research.

By use of the research approach it is apparent that the topic “process mining” already is researched quite extensively. However, the topic “business rule mining” does result in a lower number of hits during the search for existing literature, which is an indication that further research in connection with this topic will be of added value. In addition to the aforementioned, conformance checking has been performed and researched by several studies. However, research specifically towards the purchase process, including the process steps between creating a purchase order, recording the goods receipt, recording the invoice receipt and clearance of the invoice has not been investigated. Specifically, the last process step of the clearance of the invoice is not investigated in combination with the other aforementioned process steps.

This research is part of the research group from the Open University, in which several students perform a research in relation to the “business rule mining” domain. By use of this research group the students periodically discuss upon their literature review, research approach and conclusions, which subsequently serves as input for this research.

2.2. Results of the literature review

As already described in chapter 2.1, the research approach is divided in two parts, being the business rule mining by use of an existing dataset and the conformance analysis between the “as is” and the “to be” situation. Consequently, the results of the literature review are divided in a similar way, starting with the business rule mining, thus extracting the business rules from the data set.

As a result of the availability of more event data and furthermore more evolved process mining techniques, it has become possible to discover the actual processes within an organization (W.M.P. van der Aalst, 2011). Process mining can be described as the extraction of knowledge from processes recorded in event log data with the aim to discover, monitor and improve business processes (Bolt,

2018). Process mining techniques use event logs to automatically construct process models that explain the behavior observed (W.M.P. van der Aalst, 2011).

Current practice of the business process mining is dedicated to discovering models that could reconstruct complete process models from existing datasets (Tiwari, 2008). A systematic literature review on process mining and the possible applications has revealed that process mining is currently applied for many purposes and in many settings. The application of process mining focuses mainly on three areas: discovery, conformance and enhancement (Garcia, 2019). According to Van der Aalst (2011) these areas are defined as follows:

- Business process *discovery*: refers to producing a still unknown business process model based solely on an event log, using no prior information;
- Business process *conformance*: refers to comparing a business process model already known as an event log of the same business process to check whether the reality, as recorded in the log, is in line with the business process model and vice versa; and
- Business process *enhancement*: refers to modifying an existing business process model based on an event log of the same business process.

As this research aims to perform a comparison between the "as is" and the "to be" situation, the business processes mining type conformance checking is deemed applicable. For conformance checking, a predefined model of a process already exists. The model is used to validate the mined process in relation to the predefined model (Turner, 2012). An existing process model, or in this research a simplified process flow, is compared with an event log of the process that the model is describing. Modeled behavior is confronted with observed behavior. Conformance checking can be used to check if reality, as recorded in the log, conforms to the model and vice versa.

Current literature already has developed a mining tool suitable for workflow processes. Turner et al. (Turner, 2012) discuss upon several types of process mining techniques, being transition systems and regions, clustering techniques, heuristic approach, evolutionary techniques and the declarative mining approach. Taking into account the purchasing process, which does include business restrictions and thus tasks and tasks sequences, the heuristic approach of process mining is deemed appropriate.
The research of Fleig et al. (2018) is focused on process mining for business standardization in an ERP implementation project. The research of Fleig et al. (2018) uses a case study within a manufacturing organization. Fleig et al. (2018) demonstrate how process mining can be used for process decision-making during an EPR implementation project. In contrast to the aforementioned, this research will merely focus on mining the event log data from the dataset and comparing the results with the simplified process flow.

As a result of the aforementioned literature review, it is concluded that the business rule mining of event logs in relation to the purchase process is possible. In addition, by use of the business rule mining a model can be developed of the purchase process. The next step in the research is analyzing the possibilities in relation the performing a comparison analysis, also known as the conformance check, between the "as is" and the "to be" situation.

Business rules guide the operation of an organization. Thus, its documentation provides an important source of information both for developing technological solutions (information systems, databases) and for evaluating information systems implementations (Crerie, 2009). Business process models can serve as an instrument to express and clarify the course of activities in the context of value creation in organizations (Curtis, 1992). Business process models are representations of business processes

which provide the basis for several different tasks of Business Process Management (BPM) (W.M.P van der Aalst, 2013), such as process implementation, execution, controlling or systematic process improvement (C. Houy, Fettke, P., Loos, P, 2010).

Typically, there are discrepancies between the actual workflow processes and the processes as perceived by management (W. M. P. Van der Aalst, Weijters, T., Maruster, L. , 2004). Existing process models can be validated using conformance checking techniques (W.M.P. van der Aalst, 2011).

Business process mining can be used as a tool to explore in what manner people within an organization actually execute their transactions, and use the tool for variance analysis, being a comparison between the mined processes and the predefined ruleset (Wen, 2009). Thus, process mining could be used for a "delta analysis", i.e., comparing the actual process with some predefined process. Note that in many situations there is a descriptive or prescriptive process model. Such a model specifies how people and organizations are assumed/expected to work. During this research this descriptive or prescriptive model is referred to as the generally accepted process flow. By comparing the generally accepted process model with the discovered model, discrepancies between both can be detected and used to improve the process (W. M. P. Van der Aalst, Weijters, T., Maruster, L. , 2004).

The most common form of a graph to utilize the mined event logs is the directed graph. The directed graph can be used to visualize the mined processes. Usually, it should be relatively straightforward to set up a directed graph that contains the generally accepted process flow, as the ruleset is predefined and clearly set up.

Thus, taking into account the relevant literature, the "to be" situation, being the generally accepted process flow, can be compared with the "as is" situation. A comparison between both process flows can be relevant for different stakeholders, such as business process managers, process owners, risk managers, general management and internal audit. It is essential for this group of stakeholders to create and define processes on a high level but also to verify, predict and optimize the actual implementation (Gehrke, 2010).

2.3. Objective of the follow-up research

The objective of the follow-up research is to set up a simplified Petri net model in relation to purchasing process that can be used for further conformance analysis between the simplified model and the event logs as included in the BPI Challenge 2019 dataset. In order to do so, an additional objective is to explore the data set, including the event logs, and perform further process mining by use of existing literature and tooling such as ProM. In order to explore the data correctly further research is performed in relation to the given dataset. After the exploration of the dataset, the extracted and cleaned dataset is then imported in ProM to perform further analytics on the business rule and process mining.

Furthermore, this research requires a comparison between the simplified purchasing process and the mined ruleset from the historic dataset. As such, it is investigated how both rulesets can be composed in such a way that these are comparable and thus a variance analysis can be performed.

As a result of this research, a model is argued upon towards a comparison analysis between a generally accepted process flow and a dataset with events logs. The model delivers insights in a method towards setting up a comparison analysis, in which the advantages and shortcomings are discussed upon. The

comparison analysis delivers insights in the differences between the generally accepted process flow and the actual dataset, which can deliver stakeholders valuable information to improve their processes. The origin of these differences are discussed, which helps in understanding the current ruleset and why it is implemented in such a manner. Furthermore, it is possible to adjust for the desired ruleset and thus enhance the current implementation of the given ruleset.

3. Methodology

This chapter contains the justification of the research design and the conducted empirically research in relation to answering the research questions as formulated in chapter 1. Furthermore, this chapter describes the conceptual design and analysis of the corresponding data and information and is completed with a reflection on the research method.

3.1. Conceptual design – selection of the research method(s)

Generally, a research method can be a quantitative approach or a qualitative approach. A way to distinguish between both approaches is to identify the numeric data (numbers) or the non-numeric data (words, images and other material). As such, a quantitative method is often used as a synonym for a data collection technique that generates or uses numerical data. The dataset as retrieved from the BPI Challenge 2019 (Van Dongen, 2019) can mainly be identified as a quantitative dataset, containing different data within a complete set. The qualitative method is often used as a synonym for a data collection technique that generates or uses non-numerical data (Thornhill, Saunders, & Lewis, 2016).

The data collection and data analysis can be divided towards the (i) actual historic data which is retrieved from the BPI Challenge 2019 (van Dongen, 2019), referred to as the “as is” situation, and the (ii) simplified generally accepted process flow, which is referred to as the “to be” situation. The dataset is used to perform an exploratory data analysis. This is an approach in which diagrams are used to explore and understand the data (Thornhill et al., 2016). Thus, the data used in the research is identified as qualitative data. Therefore, the research is deemed a qualitative research.
Qualitative research is often associated with an interpretive philosophy (Denzin & Lincoln, 2011). It is interpretive because researchers need to make sense of the subjective and socially constructed meaning expressed about the phenomenon being studied (Thornhill et al., 2016). The research strategies that are related to qualitative data are varied, for which this research chose a case study. A case study is an in-depth inquiry into a topic or phenomenon within its real-life setting (Yin, 2014). The case within a case study can be related to among others a change process or an event, which both are embedded in the research questions of this study. In addition, a case study is specifically suitable when the limits of the study and its context are not evident.

3.2. Design and analysis of the data and information

In the aforementioned paragraphs the “as is” and “to be” situations are discussed, for which reference is made to chapter 2. The “as is” situation is referred to the current situation of the business rules within an entity and the “to be” situation is referred to the generally accepted business rules. In order to perform the research, both elements are retrieved.

The variance analysis can also be identified as conformance checking. Conformance checking techniques verify whether the observed behavior recorded in an event log matches a modeled behavior. This analysis is important, as often real process executions differ from the predefined process models (De Leoni, Maggi, & van der Aalst, 2012). What is identified as being the unique element within this research is the simplified generally accepted process model. Usually, the conformance analysis is performed between a complete dataset with event logs and the allowed process flow extracted from that same dataset. Then, variances can be identified between the allowed process flow and the complete event log. The general principle of segregation of duties is already described upon in chapter 1, in which it is mentioned that usually only a few process steps are of key importance within that process. For these process steps, a minimum of segregation of duties is required towards mitigating any risks of fraud or on misstatements. The generally accepted simplified process model only contains the process steps that are of key importance for the minimum of segregation of duties. When comparing that simplified model with a complete dataset, a relatively straightforward comparison analysis can be performed, directly identifying if any of the key process steps are included within that event log, being the dataset.

By use of the conformance checking, deviations are identified between the “as is” and “to be” situation. In order to do so, the event logs are aligned, if possible, with the existing dataset. This research is therefore focused on the alignment of event logs of the given dataset with the generally accepted process flow, and as such tries to determine to optimal alignment for the purchase process. As the optimal alignment is defined, a comparison analysis is performed.

3.3. Reflection on the research method

A common challenge of qualitative research is that it researches a case from which the explored circumstances are complex and dynamic. To assure reliability, it is important to document and explain the research design with sufficient detail, including a clear description of how the data was retrieved and the rationale behind design choices and used methods (Thornhill et al., 2016). A single case study does not contribute to a higher validity. However, this research proposes a model to define the optimal alignment of event logs of a purchase process between a simplified generally accepted process flow and an existing dataset in order to perform an adequate variance analysis. This model, which in this research is pinpointed towards the purchasing process, can be used for other processes.

Nevertheless, this research contains a relatively general case study, which can be applied to a high number of comparable case studies. Therefore, the research method is deemed sufficient and appropriate to the research questions.

4. Results

Within this chapter the results of this research are described. Before the describing the results by use of the conformance analysis, it is described how the data is prepared and what the results are from the initial inspection of the logging data. Furthermore, the Petri net set up is described upon. By use of these preparatory steps the conformance analysis is performed between the Petri net model, containing the simplified process model, and the dataset with event logs.

4.1. Data preparation and inspection of logging data

For the BPI Challenge 2019 dataset (van Dongen, 2019) has been collected from a large multinational company operating within the Netherlands, in the area of coatings and paints. The BPI Challenge 2019 dataset contains over 1,5 million events for purchase orders submitted in 2018. The data shows the purchase to pay process (without the approval workflow of the PO's and the invoices). The data refers to many different categories of goods and services and include many different types of vendors.
The data contains event logs in relation to the purchase order handling process for 60 subsidiaries. The original dataset contains 1,595,923 events logs related to in total 251,734 cases. The cases within the dataset are mainly related to purchase orders and the corresponding purchase items. The time-stamped events can contain one of the in total 42 activities, which among others include "Create Purchase Order Item", "Record Goods Receipt", "Vendor creates invoice", "Record Invoice Receipt" and "Clear Invoice". Furthermore, additional data is included per event, which refer to the associated informational attributes. These attributes include the value, the vendor, the category of the event and the system user. Based on the terminology present in the data, it is concluded that the system in use is a commercial product made by SAP (van Dongen, 2019).

The ruleset and dataset are applicable for the purchase process. The purchase process is relevant for many organizations, as the process directly leads to an outflow of cash. Therefore, seen the outflow of cash, the control framework, including the segregation of duties within these processes, should be designed in an adequate manner. By use of an adequate process, the risk of misstatements or potential fraud can be mitigated towards an acceptable level. The purchase process contains several process steps, which are to order the goods or services, the approval on the purchase order, the receipt of goods or services, the receipt of the invoice, the approval of the invoice and eventually the payment process. The underlying rules are therefore aligned with the process steps. For example, the process step of an approval of a purchase order contains business rules that are related to who and to what extent a function or person can approve purchase orders.

The dataset contains a number of cases that have timestamps not directly within one appropriate period, such as 1991 un till 2019. These timestamps are outside of the date range specified in the challenge instructions, which could argue that these events are incorrectly registered. This research has applied a date filter to only allow cases, thus include multiple event logs, that start and end within the first half year of 2018, thus from January 2018 un till June 2018. In addition, filters are set on the event types only including the following event types: "Record Goods Receipt", "Create Purchase Order Item", "Vendor creates invoice", "Record Invoice Receipt" and "Clear Invoice". Reference is made to paragraph 4.3 for further elaboration on the event type filters. This reduces the dataset to 722,478 events which are included in a total number of 127,110 cases, retaining 45% of the original dataset. The decrease of 55% already indicates that the dataset contains a great number of event logs different than the aforementioned event types, which in this research are not identified as a required

segregation of duty process step. Table 1 indicates an overview of the total events, including the occurrence of the start and end events.

Event type	**Occurrence (absolute)**	**Occurrence (relative)**
Record Goods Receipt	147.387	20,40%
Create Purchase Order Item	126.748	17,54%
Vendor creates invoice	114.269	15,82%
Record Invoice Receipt	99.094	13,72%
Record Service Entry Sheet	88.411	12,24%
Clear Invoice	67.467	9,34%
Other event types (34)	79.102	10,95%
Start events	**Occurrence (absolute)**	**Occurrence (relative)**
Create Purchase Order Item	123.043	96,80%
Other event types (7)	4.067	3,20%
End events	**Occurrence (absolute)**	**Occurrence (relative)**
Clear Invoice	64.314	50,60%
Record Invoice Receipt	21.545	16,95%
Record Goods Receipt	11.988	9,43%
Create Purchase Order Item	7.375	5,80%
Other event types (26)	21.888	17,22%

Table 1: overview event logs filtered

By use of the table 1, it is concluded that not all cases have finalized, as only 50,60% of the cases end with the event type “Clear Invoice”. As aforementioned, the dataset contains different timestamps, why it is important to distinguish between cases that are complete (thus a case that contains the end event type “Clear Invoice” event or “Record Goods Receipt” in consignment cases) and cases that still were in progress when the dataset was extracted. There are also multiple event types that are indicators of the starting event. In this research, only the event type “Create Purchase Order Item” is deemed the correct starting event. As such, an additional filter is deemed necessary in order to determine that the dataset does not contain cases that started before 2018 and continued during 2018, which would lead to inadequate conclusions.

Before any discovery analysis is performed, pre-processing of the raw log file is necessary in order to automatically link the events as modelled in the Petri net to the events in the log file. It is necessary to align the naming of the events. In order to increase the comprehensibility of the results, it is also recommended to rename the event names of system-based process executions. In the data, each purchase order (or purchase document) contains one or more line items. For each line item, there are roughly four types of flows in the data: (1) 3-way matching, invoice after goods receipt, (2) 3-way matching, invoice before goods receipt, (3) 2-way matching (no goods receipt needed) and (4) consignment (van Dongen, 2019). The consignment process is not deemed a frequent process flow within a generally accepted process flow of the purchasing process and as such is deleted for research purposes. This would not affect the results of the research, as the simplified generally accepted model as set up within Petri net, for which is referred to chapter 4.2, is merely related to the 3-way and 2-way matching type of process flows.

Thus, in order to prepare the data accordingly, additional filters have been inserted towards excluding the consignment process and excluding any non-complete cases. This reduces the dataset to 328,025 events included in a total number of 62,012 cases. The final filtered and prepared dataset used for further analysis is summarized within table 2.

Event type	Occurrence (absolute)	Occurrence (relative)
Record Goods Receipt	74.049	22,57%
Record Invoice Receipt	64.702	19,72%
Clear Invoice	63.655	19,41%
Vendor creates invoice	63.607	19,39%
Create Purchase Order Item	62.012	18,90%
Start events	**Occurrence (absolute)**	**Occurrence (relative)**
Create Purchase Order Item	62.012	100,00%
End events	**Occurrence (absolute)**	**Occurrence (relative)**
Clear Invoice	62.012	100,00%

Table 2: overview event logs filtered additionally

Reference is made to the number of start and end events, which are in agreement with each other. This alignment means that the dataset only contains start events related to the event type “Create Purchase Order Item” and end event related to the event type “Clear Invoice”, which is in accordance with the generally accepted process flow. Furthermore, this means that the filtered dataset only contains completed cases which have started with the expected event type. For a complete overview of the dataset in a Petri net reference is made to paragraph 4.3.

4.2. Set up of the Petri net

A directed graph is set up by use of Petri net in order to visualize the simplified generally accepted process flow of the purchasing process, which includes the creation of a purchase order, creation of the invoice by the vendor, receipt of the invoice, receipt of the goods and the clearance of the invoice.

To make drawings, it helps to assume that a directed graph has an overall flow or direction, such as top to bottom (Gansner, Koutsofios, North, & Vo, 1993). Two different directed graphs with a top to bottom directions can be compared. As the directed graphs of the “as is” and “to be” are drawn up from top to bottom, a variance analysis is performed between both. This variance analysis verifies whether the “as is” and “to be” are aligned.

This research has set up a Petri net model which includes a simplified generally accepted process flow for the purchasing process. The Petri net model for the purchasing process is modelled by use of the software application Yasper. Yasper is a tool that helps in modelling process steps and also can simulate those process steps. The process flow contains the payment process, also referred to as invoice clearance, which has not been address by current literature. The contribution and results of this research can possibly be generalized and increase the contribution to current literature.

The research focuses on the purchase process, in which certain business restrictions should be implemented. In general, the purchase process has consistent restrictions compared between different types of organizations. For instance, a production organization and hospital both have a purchase process, during which goods are received, invoices are received and approved and eventually the invoice is paid by the entity, as a result of the appropriate approvals. As an example, the purchase process includes the approval of the payments performed, which in general is restricted to certain roles, such as the chief executive officer or the chief financial officer. Condition action assertion and authorization action assertion serve, respectively control, the execution of an action in accordance with business restrictions and limit the execution of an activity to who can run it (Crerie, 2009).

In order to model a Petri net that can be used for the research, a discovery analysis of the research dataset is executed by use of a Petri net model of the complete dataset used for this research. Such a discovery analysis is of relevance for the full problem domain and not only of relevance for the case within this research, being the purchasing process of a large multinational company operating within The Netherlands, in the area of coatings and paints. For the Petri net model of the dataset reference is made to figure 2. By use of the discovery analysis the event types have been identified that identify with the generally accepted process flow, which then are used as such within the simplified Petri net model.

The Petri net model for the purchasing process is modelled by use of the software application Yasper. Yasper is a tool that helps in modelling process steps and also can simulate those process steps. In relation to this research Yasper is only used as a tool to set up a simplified model within Petri net. The concept in this regard is that a Petri net model is set up in relation to the simplified generally accepted process model, in this research by use of Yasper. The simplified purchasing process model visualizes the steps of a process and shows in which order the steps should be processed. The software application Yasper applies Petri nets as the technique for modelling. The Petri net, thus the simplified model, is saved as a PNML-file, which as such is imported within the process mining software application ProM for further conformance analysis purposes. In figure 1 the generally accepted process flow for the purchasing process is obtained within a Petri net model, constructed by use of Yasper. It is apparent that the constructed process flow is simplified and contains only five steps that are deemed of key importance within the purchasing process.

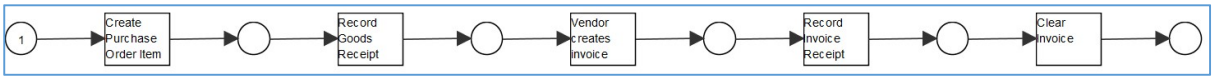

Figure 1: Petri net model

The generally accepted process model contains only one flow of events within the case as used during this research, also referred to as one sequence chain of events. The constructed flow of events for this research is only related to the purchasing process, being the case used. However, the conceptual method is generally also applicable for the problem domain, as such a simplified model can also be constructed for the sales process, or other processes as such. In order to understand the purpose of the research, reference is made to the limited number of process steps within the generally accepted simplified model, as obtained in the Petri net in figure 1. These five process steps are argued for relevance as being minimally required within the segregation of duties within a purchase process. The process flow starts with the creation and as such the placement of the purchase order, referred to as the event type “Create Purchase Order Item”. After the creation of the purchase order, the goods are received. As the dataset is related to a large multinational company operating within The Netherlands, in the area of coatings and paints, it is obvious that mainly goods are received within the purchasing process. Obviously, also the receipt of only services are part of the dataset, however such a process flow should then only exclude the event type “Record Goods Receipt” and match with the other process steps. Usually, within the simplified purchasing process model, the next step is the receipt of the purchase invoice. However, in order to start the receipt of the invoice, the vendor has to create the invoice, as such this process step is obtained between the receipt of the goods and the receipt of the invoices. The last process step in this simplified model is the clearance of the invoice, which is also referred to as the payment of the invoice.

In this research only one flow of events is constructed, as obtained within figure 1 and described above. This generally accepted process flow is deemed sufficient in order to perform the conformance analysis and determine the corresponding results and conclusions.

4.3. Conformance analysis

The predefined ruleset can also be referred to as the business rules within the organization. Business rules are key in organizing the business as they help the organization in executing the activities in conformity with the design of these processes. A business rule is simply a rule that defines or constrains some aspects of the business. In this regard, business rules are designed to control or influence the business and to determine the business structure. However, is not necessarily restricted to the business jurisdiction of the applicable entity. Business jurisdiction means that the business can enact, revise, and discontinue their business rules as they see fit (Ross, 2009). The documentation of the procedures and concepts related to an organization is recently gaining more importance and attention. In this context, business rules are essential (Crerie, 2009). Business rules therefore also support the segregation of duties within an organization. The basic principle of segregation of duties is that certain functions or process steps are segregated from each other. Without the segregation of duties within the key processes, fraud and error risks are far less manageable.

In this research the following successive steps are taken to set up the conformance analysis:

1. A directed graph is set up by use of Petri net in order to visualize the simplified generally accepted process flow of the purchasing process, which includes the creation of a purchase order, receipt of the invoice, receipt of the goods and the clearance of the invoice. Reference is made to chapter 4.2 for the set up of the Petri net model.
2. Exploring the BPI Challenge 2019 dataset in order to identify the actual purchasing processes within. By use of the discovery algorithms within ProM the actual processes are identified, which can deviate due to different algorithms.
3. Setting up the correct parameters in order to perform the conformance analysis between two identifiable process flows, being the Petri net model and the process flow as extracted from the event logs. Reference is made to paragraph 4.1 for the parameters used.
4. Perform a conformance analysis between the Petri net model, which includes the simplified generally accepted process flow, and the filtered event log.

In relation to the first step a fitness test between the event logs and the model can be measured. Fitness means the extent to which the observed process complies with the control flow specified by the prescribed process model. Probably only in the ideal world, a process model and a log have both 100% fitness, and behavioral and structural appropriateness. Rozinat and van der Aalst (2008) expect that in a practical setting the fitness dimension is typically more dominant. Therefore, they recommend carrying out the conformance analysis in two phases; (1) the analysis of fitness, and subsequently (2) the appropriateness of the model.

According to Van der Aalst (2011) the conformance analysis refers to comparing a business process model already known as an event log of the same business process to check whether the reality, as recorded in the log, is in accordance with the business process model and vice versa. In this research, the conformance analysis is performed between the generally accepted process flow, also referred to as the simplified model and set up within a Petri net, and the dataset containing the actual event logs. Most probably only within a perfect world, a simplified process model and an event log have both 100% fitness, including behavioral and structural appropriateness.

With respect to the research, a comparison is set up, to which the business rules are compared with the event logs. The business rules are obtained within a Petri net process flow. By use of the event

logs, different process flows can be identified. As such, the problem of comparing these process flows can be deemed relevant (Bolt, 2018).

Within this research, including the corresponding case, conformance analysis is not performed on the complete dataset with event logs. Only cases that include event types “Record Goods Receipt”, “Create Purchase Order Item”, “Vendor creates invoice”, “Record Invoice Receipt” and “Clear Invoice” are selected towards the conformance analysis. By use of this filter on the dataset, those cases can be compared with the generally accepted simplified process model, which also contains the same event types. As such the Petri net model, containing the generally accepted simplified process model, and the filtered dataset are comparable, which makes the conformance analysis possible.

This does not mean that other event types are excluded, which is also visible within figure 2, containing a Petri net of the used dataset. By use of the additional filter, for which is refer to paragraph 4.1, only the cases are obtained within the dataset that are relevant for the conformance analysis with the generally accepted process flow, as obtained within a separate Petri net.

In order to discover the dataset and verify the event logs and the event types within, a Petri net is set up by use of the Inductive miner. The Inductive Miner is performed on the dataset which includes the first half year of 2018, containing no consignment event types and only contains cases with a start and end event. The Petri net is obtained in figure 2.

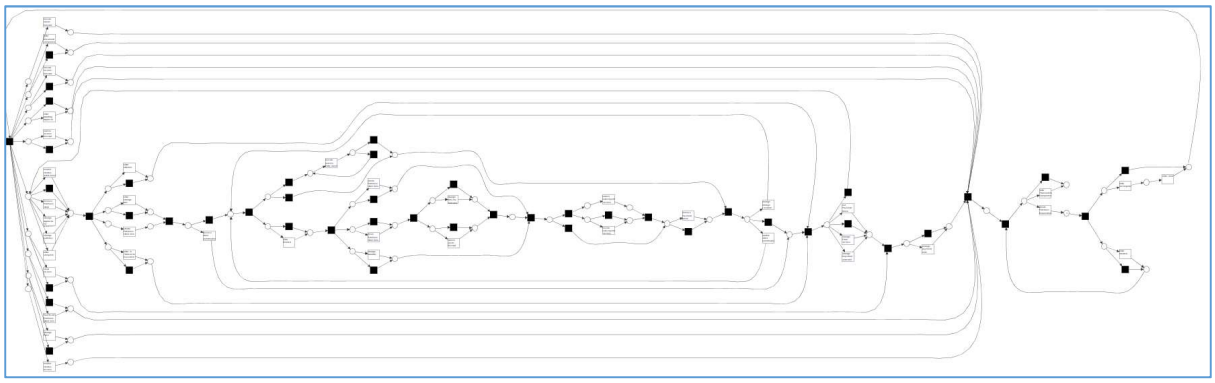

Figure 2: Petri net on filtered dataset

It is apparent that the dataset contains multiple process flows, which also means that the dataset used contains multiple cases, that somehow include different event types other than the event types to be used in this research. In order to obtain a simplified overview of the process flow related to the filtered event types the Inductive visual Miner is used, which reconstructs that actual flow of events within the process. This analysis is obtained within figure 3, noting a simplified overview of the actual events within the dataset, related to the filtered event types.

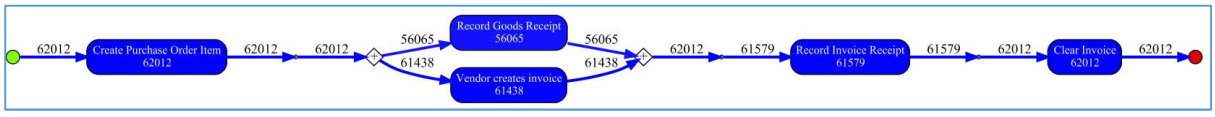

Figure 3: Mine with Inductive visual Miner

Reference is made to the process steps “Record Goods Receipt” and “Vendor creates invoice”. Apparently, these process steps do not succeed each other but both are subsequent after the creation of the purchase order and an input value for the record of the invoice receipt. Nevertheless, both event types are included in the simplified Petri net model and as such are included in the conformance analysis.

With respect to the conformance analysis the algorithm “Replay a Log on Petri net for Conformance analysis” has been used. The log replay is carried out in a non-blocking way and from a log perspective, i.e., every log trace is replayed in the model and tokens that are missing to fire the transition in question they are created artificially and replay proceeds. While doing so, diagnostic data is collected and can be accessed afterwards (ProM Framework, 2017). The performance of the process is calculated and projected on the Petri net model, which in this research is the simplified Petri net model. A red colored transition indicates that there are traces within the event log that to not correspond with the Petri net model. In figure 4 the visual output of the conformance analysis is obtained.

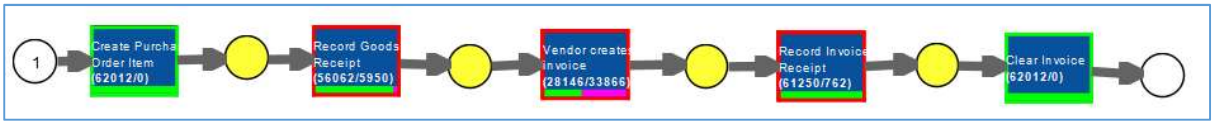

Figure 4: Visual output by use of the algorithm “Replay a Log on Petri net for Conformance analysis”

Fitness analysis is concerned with the investigation whether a process model is able to reproduce all execution sequences that are in the log, or, viewed from the other angle, whether the log traces comply with the description in the model. So, fitness analysis aims at the detection of mismatches between the process specification and the execution of particular process instances (ProM Framework, 2017). The trace fitness from the model perspective is 86%. A deeper understanding of the trace fitness can be retrieved from the element statistics per event type, which are included in table 3.

Event type	Traces within log and model	%	Traces only in model	%	Total traces
Create Purchase Order Item	62.012	100%	-	0%	62.012
Record Goods Receipt	56.062	90%	5.950	10%	62.012
Vendor creates invoice	28.146	45%	33.866	55%	62.012
Record Invoice Receipt	61.250	99%	762	1%	62.012
Clear Invoice	62.012	100%	-	0%	62.012

Table 3: Element statistics

Table 3 contains an overview of the event used within the conformance analysis, in which the figures and percentages show how many events, thus from start to end, as extracted from the event log contain the five process steps from the simplified generally accepted process model. It is apparent that the start and end event types “Create Purchase Order Item” and “Clear Invoice” do not deviate between the Petri net model and the dataset. This is deemed logical as the cases are filtered for a start and end event containing the aforementioned event types. Also, for the event type “Record Invoice Receipt”, only 1% of the cases as included the event log do not contain this process step. At first, this seems logical, as within the purchasing process a purchase invoice is necessary to finalize process as whole and perform the final payment (event type “Clear invoice”). However, it is noteworthy that this would suggest that 762 invoices have been cleared (i.e. paid) for which no actual invoice receipt has been recorded, which can be deemed as a conformance exception. Thus, to generalize this exception, it could be argued that such an exception could indicate that within the purchase process of this entity, increased risks on errors or fraud can be identified. In order to prevent any errors or fraud risks management should intervene and take adequate actions to sufficiently mitigate those identified risks. By use of the exception noted, the contribution of this research is already noted, as the conformance analysis with the simplified generally accepted model directly results in to some key insights for the used event log. Such a simplified model can also be set up for other process, for which management deems it relevant. In order to do so, the key process steps should be identified within the chosen process and set up by use of a Petri net. In this regard, management should evaluate which

process steps are of key importance and which process steps are deemed of lower importance, or will not lead to any increased risks on errors or fraud.

In addition to the aforementioned exception, reference is made to the event type “Vendor creates invoice”. This event type aligns only 45% with the simplified Petri net model, for which the event log does not contain the event type within the different cases for 55%. This is partially already explained due to figure 3, in which it visible that the process step “Vendor creates invoice” does not necessarily follow upon the “Record Goods Receipt”. The BPI Challenge 2019 dataset does not completely explain the full process flow, which could explain the exception in relation to the event type “Vendor creates invoice”. Nevertheless, it is a noteworthy exception which can result to relevant insights.

A great number of the so-called conformance exceptions are most probably related to real exceptions. These exceptions as mentioned above can be caused by use of the simplified Petri net model as used for the conformance analysis. Purchases without any goods involved, thus services, or loops of multiple recurring goods and invoice receipts in a row have not been obtained within the simplified Petri net model. This result into the case that any recurring events, such as whereas goods are received multiple times within one case, are reported upon as an exception within this conformance analysis. Nevertheless, the concept of the conformance analysis between the simplified generally accepted process model and the event log has resulted in the identification of most probably noteworthy exceptions, and as such proving its relevance for current literature. The basic concept is by design deemed fairly straightforward, taking a few key process steps from a certain process and determining if the key process steps are included in the event log. In the event of any exceptions, these would directly give important insights, as it is expected that all of those key process steps should be included in the events. In this regard it can be argued that the management of different enterprises can identify different key process steps, which obviously is dependent on the size and type of activities. However, for instance within the purchasing process, the authorization of the payment will be for a great number of entities of key importance. These entities can deviate from a hospital to a production facility, payments usually should still be performed and are as such included in the purchasing process. Therefore, it can be argued that a generally accepted process model within a Petri net can give a great number of entities, deviating from a hospital towards the production facility, meaningful insights when performing a conformance analysis with the event log of those entities.

5. Conclusions and discussion

In this chapter the findings of this research based on the practical experiences using the BPI Challenge 2019 event log are described. In this regard the conclusions as result of the conformance checking between the Petri net and the dataset containing event logs is discussed upon. Also, further discussion in relation to the proposed model and conclusions is obtained, discussing upon the limitations and possibilities for future research.

This research is an addition to the current research in relation to business rule mining. The research of Hakvoort (2008) is towards the conformance analysis from a financial audit perspective. In the research of Hakvoort (2008), the purchasing process is used to performed conformance checking between a simplified model and a dataset. However, that research is limited to the purchase order, receipt of goods and receipt of invoice and does not take into account the clearance of the invoice. In this research is referred to the clearance of the invoice, which is comparable with the actual payment of the invoice. As the payment of the actual purchasing invoice is deemed an important step in the process, this research expands on the research performed by Hakvoort (2008).

As mentioned earlier, big data is becoming more and more important and relevant. Therefore, identifying the business rules within this data is also of crucial importance. The design of processes, also known as the predefined ruleset, and the implementation of the processes, which is visible by use of the existing dataset, are both key for enterprises. Analyzing if the processes are actually executed in the way that these are designed is very relevant, which includes the minimum of segregation of duties within an organization. When the processes are not executed in the way that these are designed, the enterprise may be subject to potential risks such as loss of money or loss of knowledge. Furthermore, this research already notes upon the importance of segregation of duties within certain processes. A simplified but generally accepted process flow could contain the minimal of segregation of duties that would be sufficient for certain organizations. This would mean that, when the dataset does conform to the simplified generally accepted process model, the minimum of segregation of duties would be in place, decreasing the risk for fraud and errors.

Conformance analysis does provide tooling in order to achieve a differentiation analysis between conforming and deviating process instances, related to an event log and the process model. The model used in order to perform the conformance analysis between the simplified Petri net model and the dataset does result in useful insights, by which it can be concluded that for 62,012 cases the dataset significantly confirms with the simplified Petri net model. Also, explanations have been given for the conformance exceptions, meaning that these were not completely unexpected. The objective of this research was to set up a simplified Petri net model that can be used for further conformance analysis between the simplified model and the event logs. In this regard a conformance analysis has been performed with the Petri net model, containing a simplified generally accepted process model, and valuable conclusions have been taken, which are described hereafter. As such, this research has adequately set up a method in order to perform a conformance analysis between a Petri net model, containing a simplified generally accepted process model, and a dataset containing event logs. This model is within this research specified towards the purchase process. However, a great number of processes exist for which such a method could be valuable. As an example, the model can also be used for the sales process, in which certain process steps are deemed required in order to set up an effective sales process with the minimally required segregation of duties. The visualization and analysis functionality within ProM, which for this research is set up by use of the algorithm “Replay a Log on Petri net for Conformance analysis” does help in understanding the analysis and drawing conclusions.

This research uses data from the BPI Challenge 2019. Despite that this is a merely used dataset for research purposes and extracted from a multinational company operating from The Netherlands in the area of coatings and paints, this research does not take into account other datasets that are, or could be, extracted from different systems. Nevertheless, it could be argued that the data used for this research is comparable with data which can be extracted from different systems. This is supported by the fact that the data is from a real company, contains a great number of different process flows, for which is referred to figure 2, and it is concluded that the system used for the dataset is a commercial product made by SAP (van Dongen, 2019). In addition, this research uses an example set that includes the purchasing process. For this it is argued that a minimum of segregation of duties should be included in any purchasing process, related to the creation of a purchase order, record invoice receipt, record goods receipt and the clearance of the invoice. It can be argued that the minimum should be extended to other relevant process steps, such as an authorization of the changes of master vendor data.

Towards preventing that the analysis contains false positives, meaning that process steps that are concluded as conformance exception but should be allowed, it could be relevant to further extend the simplified Petri net model with other permitted process steps and corresponding paths. Additional research could be relevant in creating simplified process models in Petri net that extend the current Petri net model used in this research. During the setup of the simplified process model within Petri net it is noticed that taking in to account that actual dataset which will be used is key. Before the Petri net model was constructed, a discovery analysis has been set up in order to determine the key process flows within the dataset. By use of the discovery analysis, the additional process step "Vendor creates invoice" was added, as this process step marked the start of the subsequent process steps. This contributes to an extension of the simplified Petri net model and that other process steps could be taken into account into future research.

It can be concluded that this research has set up a simplified Petri net model and performed a conformance analysis with an existing dataset containing event logs, resulting in valuable insights in relation to the minimally required process steps. Nevertheless, as aforementioned, sufficient research possibilities are available in order to extend the research related to simplified Petri net models and the corresponding conformance analysis.

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